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# INTRODUCTION OF THE NORTH ATLANTIC ASCIDIAN *MOLGULA MANHATTENSIS* (DE KAY) TO TWO AUSTRALIAN RIVER ESTUARIES

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ABSTRACT

Populations of the North American (Atlantic coast) *Molgula manhattensis* have been sampled at Newport Power Station in the mouth of the Yarra River, Victoria; and at several stations up to 22 kilometres from the mouth of the Brisbane River. The species and its affinities are discussed in detail, together with the implications of its distribution and its occurrence in Australian estuaries.

Eleven Stations in the Brisbane River, from its mouth to 70 km upstream, have been sampled by Mr R. Monroe at 3 monthly intervals from May 1974, following a major flood in January. In May 1975 two specimens (1·5 cm and 1·0 cm in diameter, respectively) of *Molgula manhattensis* were taken off Mowbray Park, some 16 km upstream. In August large numbers of the species were present at this site, and even larger numbers were taken up to 6 km further up the river in the South Brisbane Reach. By December only 3 specimens were taken at the latter station. Downstream, the species was taken only once, and in small numbers. The species was not present in samples taken in January 1976.

From May to August is the winter season of low rainfall and during that period highly seasonal populations of *Molgula* spp. are present in Moreton Bay (Kott 1972). *M. manhattensis* has not been taken in Moreton Bay, however, and it is most likely that parent stocks from which the riverine populations were recruited were located on shipping (from the western Atlantic via the Panama Canal) in the Port of Brisbane. This extends up the Brisbane River to within 3 km of the South Brisbane Reach.

In the family Molgulidae, it is known that sexual maturity is achieved early, in individuals of small size (Berrill 1931); while the spiral arrangement of stigmata in this family provides a means whereby maximum filtration area is available in small individuals to contribute to this general metabolic efficiency. Kott (1972) suggested that these factors would represent advantages where populations suffered seasonal mortality resulting from the periodic flooding, silt deposition, and temperature fluctuations that commonly occur in sheltered bays. The large molgulid renal organ (see Berrill 1950) could also represent an advantage in these locations.

In fact, 7 of 12 free living ascidian species in Moreton Bay are molgulid species (Kott 1972); and *M. mollis* and *M. sabulosa* commonly occur in Port Phillip Bay (Kott, in press). Of 29 species reported on from America (Van Name 1945) 7 are recorded from harbours, estuaries, and river mouths; 6 are recorded from intertidal or shallow waters; and 11 occur in shallow waters in polar regions where melting ice causes seasonal dilution of sea water.

*Molgula manhattensis* (de Kay) and the closely related *M. tubifera* (Orsted) appear to have developed the capacity to withstand brackish conditions to a surprising extent. The combined records of both species (> *M. manhattensis*: Thompson 1930; Berrill 1950) range 'from the White Sea to the tropics in water whose salinity varies from 16 to over 30‰' (Thompson 1930, p. 23). Berrill (1950, p. 248) has also commented on their tolerance of the 'diluted and polluted waters typical of estuaries and harbours'. Van Name (1945, p. 388) refers to the western Atlantic *M. manhattensis* as 'one of the few ascidians that will live in water of somewhat diminished salinity'.

It is not altogether surprising, therefore, that it is *M. manhattensis* which has been introduced into Brisbane River, some 22 km from its mouth, where the bottom salinity (registered at the Port Office, in the Town Reach of the river, between the stations sampled off Mowbray Park and in the South Brisbane Reach) was in the vicinity of 16‰ in

May 1975; 19‰ in August 1975; 25‰ in September 1975; and 11‰ in December 1975.

It is not impossible that there have been earlier introductions that were eradicated by the January 1974 flood. It is also possible that introduced riverine populations do not withstand the summer rainfall period and that, unless the species has become established in refuges in Moreton Bay, subsequent recruitment (if any) will also be from ships hulls.

Apart from the fact that *Molgula manhattensis* of 1·2 cm diameter from Woods Hole in September 1927 had attained sexual maturity (Berrill, 1931), little is known of the growth rate and breeding season of *M. manhattensis* and this must be largely inferred from what is known of related species. *M. tubifera* (closely related to *M. manhattensis*) has been found breeding at Plymouth in all seasons other than winter (March to October; Berrill 1931, 1935). *Molgula mollis* (> *M. sabulosa*: Kott, 1972) is a species of similar size which reaches sexual maturity before reaching 2 cm in diameter. After settling in Moreton Bay at the end of winter, this species apparently produced at least one generation of offspring which grew to at least 2 cm in diameter before the populations disappeared in summer (Kott 1972). Therefore, sexual maturity is apparently attained within 2 months. If the growth rate and breeding season of the introduced populations of *M. manhattensis* are comparable with these, juveniles settling on ships in the western Atlantic in autumn could have been transported to the southern hemisphere, where their offspring settled in the Brisbane River following the period of summer rain (March 1975). Then the large mature populations sampled in August would have been adults of the second generation, progeny of the parent generation that settled in the river to reach sexual maturity in May; and the individuals taken in October would represent a third generation.

**Molgula manhattensis** (de Kay, 1843)
(Figs. 2–4)

*Ascidea manhattensis* De Kay, 1843, p. 259.
*Molgula manhattensis*: Van Name, 1945, p. 385 and synonymy.
*Molgula platei*: Arnback, 1928, p. 22, plate 1, figs. 31–4.

New Records

Brisbane R.: QM G8976, G8977, G8979 Mowbray Park (32 specimens, R. Monroe, 7.viii.1975); QM G8978, mud channel, mouth of Norman Creek (2 specimens, R. Monroe, 12.v.1975); South Brisbane Reach, below Executive Building (numerous specimens, R. Monroe, 7.viii.1975; 50 specimens including juveniles, R. Monroe, 30.x.1975; 3 specimens, P. Davies, 5.xii.1975); Bulimba corner (1 specimen, R. Monroe, 30.x.1975).

Yarra R.: NMV H301, Newport Power Station (9.i.1967).

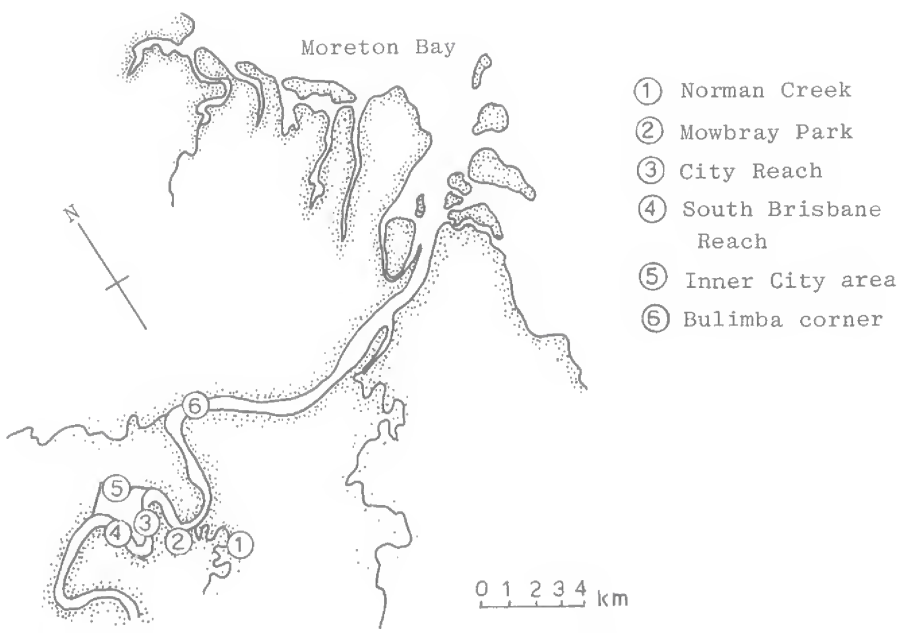


Fig. 1: Lower Reaches of the Brisbane River from the Inner City area to Moreton Bay.

### Other Material Examined

*Molgula tubifera*: AM Y1949, Duke Rock, Plymouth, U.K. (2 specimens, P. Kott, July 1951).

### Distribution

On the Atlantic coast of North America from Portland to Louisiana (Van Name 1945). *M. platei* Hartmeyer, 1914; Van Name, 1945, known only from a single specimen from Chile, is similar to the present species. If closer examination should prove them synonymous, the possibility that it had been transported between the Pacific and Atlantic coasts of America, by ship, should not be overlooked.

The species is commonly taken from shallow waters, the deepest reliable record being at 30 m (Van Name 1945).

### Description

Individuals are almost spherical, to ovoid, slightly laterally flattened, and up to 2·5 cm in diameter. Both apertures are on short siphons a short distance apart on the upper surface. The branchial aperture is turned ventrally and the atrial aperture diverges slightly in the opposite direction. The test is whitish, thin, papery and transparent. It is covered with sparse, short hairs to which mud and fine sand adhere. On the basal half of the body the hairs are longer and form root-like processes anchoring the animal into the substrate. (Fig. 2).

The body wall is very thin with muscles conspicuous only around the siphons. It is very closely adherent to the test. At the base of the branchial siphon there is a straight edged velum on both sides which reduces the opening to a longitudinal slit. Longitudinal muscles from the body wall extend into these velar folds of the siphonal lining. The branchial tentacles are very bushy. The dorsal tubercle is a circular cushion with a U-shaped opening turned posteriorly, the horns turned inwards. The dorsal lamina is very short and is joined by 3 broad transverse vessels from each side of the body.

The branchial sac has 6 narrow deeply curved folds on each side of the body. There are no internal longitudinal vessels between the folds. Those on the folds are extremely broad and project out from the ventral surface of the fold as a flat membrane. The internal longitudinal vessels become progressively wider toward the base of each fold. There are no internal longitudinal vessels on the dorsal surface of the fold. Longitudinal vessels on the ventral surface of each fold are arranged according to the formula DL 0(3) 0(4) 0(4) 0(4) 0(4) 0(3)0 E. In the very extensive spaces between the folds there are very numerous, and irregular, interstitial infundibula, with interrupted and irregular vessels extending across them (Fig. 3). The primary infundibula in each fold are subdivided into two and each subdivision is again divided at its apex in the margin of the fold. However, this arrangement is much obscured by the many irregular accessory or interstitial coils that are present, especially near the apex of the coils. In older specimens there is an unperforated area along either side of the endostyle.

The gut forms a very narrow deeply curved loop enclosing the gonad on the left side of the body. The stomach is long, with internal longitudinal glandular folds. The anal border is divided into about 12 shallow rounded lobes. On the right side the molgulid kidney occupies the usual postero-ventral position. It is long and slightly curved and increases in length as the individual becomes larger. The right gonad extends along parallel to the dorsal border of the kidney. The gonads consist of an elongate or flask-shaped ovary terminating postero-dorsally in a short oviduct. Very dense clumps of arborescent testis follicles are arranged continuously along the proximal end and the ventral border of each ovary. Only occasionally there are small isolated clumps of testis follicles on the dorsal margin of the ovary. Vasa efferentia extend from the testis follicles onto the mesial surface of the ovary where they unite into one short vas deferens on the right gonad, but on the left gonad there are up to six short vas deferens arranged along the length of the ovary. (Fig. 4).

Occasionally eggs, with follicle cells, are found in the peribranchial cavity, but no larvae were found suggesting that the species is oviparous. The eggs are 1·1 mm in diameter, excluding the follicle cells. Juveniles were present attached to the test of adult specimens in August.

### Relations

Hartmeyer (1923) and Berrill (1950) believe the European *M. tubifera* to be synonymous with *M. manhattensis*. Hartmeyer's synonymy is based on the fact that the gut loop of both *M. tubifera* and *M. manhattensis* is equally narrow and deeply curved and encloses the left ovary. Berrill's view is supported by the small eggs and oviparous habit and similar development in both species (Berrill 1928).

Despite similarities between the species, neither Arnback (1928) nor Van Name (1945) accepted the synonymy of *M. tubifera* and *M. manhattensis*. Arnback points out that the branchial sac of European specimens has fewer accessory spirals than *M. manhattensis*.

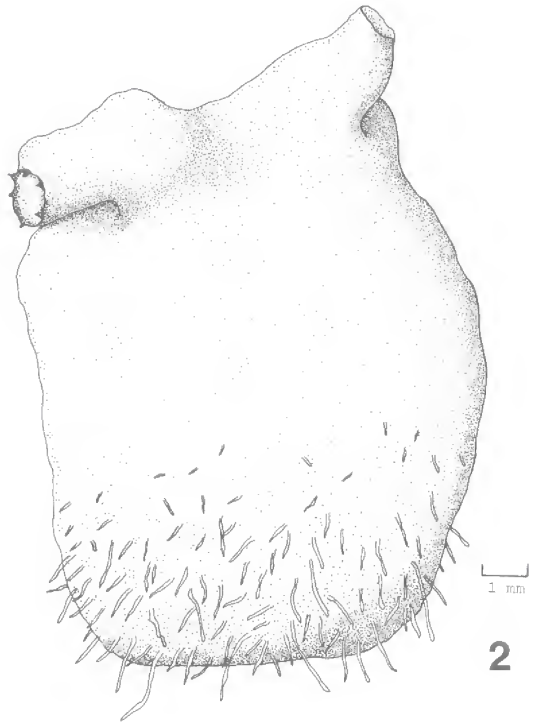




FIG. 2: *Molgula manhattensis*; external appearance (specimen from the Brisbane River).
FIG. 3: *Molgula manhattensis*; portion of branchial sac between the folds (specimen from the Brisbane River).
FIG. 4: *Molgula manhattensis*; kidney, gut and gonads on inner body wall (specimen from the Brisbane River).

Specimens from the English Channel in the collection of the Australian Museum (AM Y1949, Duke Rock, Plymouth, July 1951) have been re-examined. They resemble the present specimens of *M. manhattensis* from the Brisbane River in size and general appearance, in the number of branchial folds, in the deeply curved gut loop, in the position of the right gonad parallel to the kidney, and in the size of the eggs and testis follicles. The differences between the American *M. manhattensis* and the European *M. tubifera* are confirmed, however, and the details of these differences are set out in Table 1.

The multiplicity of short testis ducts in the present specimens from the Brisbane and Yarra Rivers is similar to that inferred for *M. manhattensis* by Huntsman, 1922, and that known for some specimens of the European species (see Arnback 1928). However, Arnback (*loc. cit.*) has drawn attention to variations in the condition of the vas deferens in a range of specimens from European locations.

The multiple short vas deferens found in *M. manhattensis* and related species was used by Huntsman (1922) to characterise the genus *Gymnocystis*. Based on this criterion *M. ampulloides* (a synonym of *M. tubifera*) was excluded from that genus.

Huntsman's subdivision of the genus *Molgula* was not adopted, however, since variations in arrangement of testis follicles relative to the ovary and variations in the length and disposition of the vas deferens occur throughout the genus, and are not considered to be of more than specific significance. The significance of this reported variation in the condition of the vas deferens in *M. tubifera* and its synonyms has yet to be resolved.

In the Australian Museum specimens from the English Channel, referred to above, a single vas deferens extends along the mesial surface of the ovary and opens near the opening of the oviduct.

The Brisbane and Yarra River specimens conform exactly in all respects with the American species *M. manhattensis* (see Van Name 1945).

Table 2 sets out the principal characters which distinguish those species in which more than a single vas deferens associated with the right or left gonad has been reported.

### Filtration Rate

The capacity of the individual to filter large amounts of water and deal effectively with the sediments filtered from the water could also be relevant to its occurrence in shallow estuaries and in other locations where there is an unusual amount of suspended matter and other pollutants.

The pronounced branchial folds of *M. manhattensis* and the complex arrangement of primary and accessory infundibula on the folds and in the interspace have developed the area available for filtration to a maximum degree.

MacGinitie (1939) and Day (1974) have shown that in *Ascidia californica* and *Pyura stolonifera* respectively, mucous moves over the pharynx in a continuous sheet. Jorgensen's (1939) assessment of filtration rate of *Molgula manhattensis* and *Ciona intestinalis* suggests that all particulate matter

TABLE 1: Differences between *M. manhattensis* and *M. tubifera*

| Species | Apertures | Internal longitudinal vessels/fold | Testis follicles | Dorsal tubercle | Stigmata | Anal border |
|---|---|---|---|---|---|---|
| *M. manhattensis* | close together on the upper surface; long when extended (see Arnback 1928, fig. 34) | never exceeds 4; present on dorsal side of fold only | not present on dorsal border of ovary | cup-shaped with unrolled horns turned to the right or posteriorly | numerous accessory spirals; long stigmata (see also Van Name 1945) | lobed |
| *M. tubifera* | a little distance apart on the upper surface; moderate length when extended (see Thompson 1930, pl. 3, figs. 1, 2) | up to 7 (Thompson 1930, p. 21; '3 to 6 mostly' 5 to 6); present on both sides of fold | present all around ovary | slit-like, S-shaped, C-shaped or U-shaped turned to the right, or left or posteriorly (Arnback 1928) | only occasional accessory spirals; stigmata short (see also Thompson 1930, pl. 3, fig. 6) | smooth |

TABLE 2: Comparison of *Molgula* spp., with Deeply Curved Gut Loop and Multiple Vas Deferens

| Species | Gut loop curve | Accessory infundibula; stigmata | Branchial folds | Maximum number longitudinal vessels/fold | ♂ follicles | Range | Reference to description |
|---|---|---|---|---|---|---|---|
| *M. herdmani* Bjerkan | shallow | rare; long | 7; pronounced | 7 | surround ovary | Norway | Arnback, 1928 |
| *M. robusta* Van Name | deep open | rare; short | 6; pronounced | 11 | surround ovary | Massachusetts | Van Name, 1945 |
| *M. siphonalis* Sars | deep open | rare; long | 7; pronounced | 7 | surround ovary | N. Atlantic | Van Name, 1945 |
| *M. provisionalis* Van Name | deep open | rare; long | 6; low | 8 | surround ovary | N.W. Atlantic | Van Name, 1945 |
| *M. macro-siphonica* Kupffer | deep open | rare; short, irregular | 6; low | ? | surround ovary | Baltic North Sea | Arnback, 1928 |
| *M. tubifera* Orsted | C-shaped | occasional; short | 6; pronounced | 8 | surround ovary | N.E. Atlantic | Arnback, 1928 |
| *M. manhattensis* de Kay | C-shaped | numerous; long | 6; pronounced | 4 | along ventral border of ovary | N.W. Atlantic | see above |
| *M. calvata* Sluiter | deep open | none; long | 7; low | 2 | surround ovary | Indonesia N.E. Aust. S.W. Aust. | Kott, 1964 |

(down to 1 micron at least) is strained from the water by this sheet of mucous.

It was possible, therefore to estimate an approximate rate at which *Molgula manhattensis* filtered the muddy water of the Brisbane River.

The filtration rate was assessed according to the formula:

$$m = \frac{(\log conc_o - \log conc_t) \times M}{\log e \times t}$$

where m is the quantity of water filtered in time t; $conc_o$ is the concentration of particles in the water at the beginning of the experiment and $conc_t$ is the concentration of particles in the water at the end of the experiment; t is the duration of the experiment; and M is the amount of water in the experimental vessel (see Jorgensen 1943).

The present experiment was conducted for a period of 12 hours with duplicate specimens of *M. manhattensis*, each in 1·3 litres of Brisbane River water with a heavy suspension of fine mud. No sedimentation had occurred in the control vessel at the end of the experiment. The concentration of particles in suspension after 12 hours is expressed as a percentage of the concentration at the beginning of the experiment, and was estimated by measured dilution of the unfiltered water to match opacity observed in the experimental vessels at the end of the experiment. The dilution achieved by the removal of suspended particles by the ascidian, over this 12 hour period was of the order of 1 in 1000.

The filtration rate of a single specimen of *Molgula manhattensis* was thus shown to be in the vicinity of 1·25 mls/minute (750 mls/hour). This rate confirms Jorgensen's (1952) values of 8 to 18 litres per hour for 15 specimens.

These small individuals are, therefore, very efficient filter feeders. The capacious and long gut loop with its pronounced typhlosolar fold undoubtedly contributes to the accommodation of large amounts of sediment from which nutriment is extracted.

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